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13. ABSTRACT (Maximum 200 words)

Progress in the higher order crossings (HOC) method included development of "contraction mapping" for the estimation of discrete frequencies in noise. Parametric filters allow the estimates to attain high precision. Reports and papers on this technique are listed, and applications to the discrimination of metal plates has begun.

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FINAL REPORT FOR 9.30.92–9.30.93

HIGHER ORDER CROSSINGS

Grant AFSOR-89-0049

Principal Investigator: Benjamin Kedem

Mathematics Department and Systems Research Center
University of Maryland, College Park, MD 20742

Tel: (301) 405-5119
E-Mail: bnk@gertrude.umd.edu

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1 Overview

During this period we have completed several works on higher order crossings (HOC) and related topics.

As outlined in our previous reports, particularly the final report for 10.1.90–9.30.92, our research led to a method called the contraction mapping method (CM) useful for the estimation of discrete frequencies in noise. Accordingly, a parametric filter is fine-tuned by a HOC sequence to lock on a frequency in noise. The obtained estimates can achieve high precision. In later versions of CM, instead of parametrizing zero-crossing counts, we have parametrized the first order autocorrelation and certain least squares estimates.

We have also experimented with HOC methods trying to discriminate in metal plates using real data from the National Institute of Science and Technology.

2 Publications

2.1 Books

1. *Time Series Analysis by Higher Order Crossings*, IEEE Press, Piscataway, NJ, 1994.

2.2 Papers in Journals and Proceedings

1. "Zero-crossing rates of functions of Gaussian processes," (With J. Barnett) *IEEE Transactions on Information Theory*, Vol. 37, pp. 1188-1194, 1991

2. "Elliptically symmetric orthant probabilities," *American Statistician*, 45, p. 256, September, 1991.

3. " Monotone Gain, First-Order Autocorrelation, and Expected Zero-Crossing Rate," (With T. Li) *Annals of Statistics*, 19, pp. 1672-1676, 1991.

4. "Fixed points in mixed spectrum analysis," (With S. Lopes) to appear in proceedings of NATO ASI, Il.Ciocco, Italy, July 1991.

5. "Contraction mappings in mixed spectrum estimation," *New Directions in Time Series Analysis*, D. Brillinger et al. eds., Vol. I, pp. 169-191, 1992, Springer Verlag, New York.

6. "Estimation of the period of periodically correlated sequences," (with D. Martin), *Jour. of Time Series*, Vol. 14, pp. 193-205, 1993.

7. "Practical aspects of a fast algorithm for frequency detection," (With S. Yakowitz). To appear in *IEEE Tr. on Communications*.

8. "Strong consistency of the contraction mapping method for frequency estimation," (with T. Li), *IEEE Tr. on Information Theory*, Vol. 39, pp. 989-998, 1993.

9. "On autocorrelation estimation in mixed spectrum Gaussian processes," (with E. Slud) *Stochastic Proc. and Their Appl.*, Vol. 49, pp. 227-244, 1994.

10. "Partial likelihood analysis of logistic regression and autoregression," (with E. Slud) *Statistica Sinica*, Vol. 4, pp. 89-106, 1994.

11. "Asymptotic analysis of a multiple frequency estimation method," (with T. Li) *J. Multivariate Analysis*, Vol. 46, pp. 214-236, 1993.

12. "Asymptotic normality of the contraction mapping estimator for frequency estimation," (with T. Li and S. Yakowitz) *Stochastic Proc. and Their Appl.*, to appear.

13. "Iterative filtering for multiple frequency estimation," (with T. Li) *IEEE Tr. on Signal Processing*, to appear.

14. "An iterative filtering algorithm for non-Fourier frequency estimation," (with J. Troendle) *Jour. of Time Series Analysis*, Vol. 15, pp. 45-63, 1994.

15. "Iteration of mappings and fixed points in mixed spectrum estimation," (with S. Lopes) *Stochastic Models*, to appear.

2.3 Submitted Papers

1. Kedem, B. and S. Yakowitz, "On the contraction mapping method for frequency estimation," submitted.

7. Lopes, S. and B. Kedem, "Spectrum analysis in FM sinusoidal models," submitted.

2.4 Technical Reports

1. "Strong consistency of the contraction mapping method for frequency estimation," (with T. Li), Tr. 92-21

2. "Asymptotic normality of the contraction mapping estimator for frequency estimation," (with T. Li and S. Yakowitz), TR-92-22

3. "On the contraction mapping method for frequency detection," (with S. Yakowitz), TR 92-45

4. "Estimation of Multiple sinusoids by parametric filtering," (with T. Li), TR 92-51

5. "Multiple Frequency Estimation in Mixed-Spectrum Time Series by Parametric Filtering," (Ph.D Thesis, T. Li Report 92-7 SRC)

3 Invited Presentations

1. "Threshold method," Statistics and Probability Day, GWU, October 20, 1990.

2. "Contraction mappings in spectrum analysis," AT&T Bell Labs, Murray Hill, NJ, October 26, 1990.

3. "Higher order crossings," Sequence of lectures on HOC, Tsinghua University, Beijing, PRC, Dec. 22, 1990- Jan. 10, 1991.

4. "Contraction mappings in spectrum analysis," Dynamics Seminar, Mathematics Dept., UOM, Feb. 7, 1991.

5. "Size distributions," Discussant, WSS, DC, January 16, 1991.

6. "HK Algorithm," USAF, Rome Air Development Center, NY, June 18-19, 1991.

7. "Fixed points in mixed spectrum estimation," NATO ASI, IL Ciocco, Italy, July 14-27 1991.

8. "Threshold method, Statistics Colloquium," Toronto University, Toronto, Canada, September 27, 1991.

9. "Higher order crossings," Washington Stat. Society. and GWU, October 10, 1991.

10. "Threshold method," Statistics Colloquium, UMBC, Catonsville, MD November 22, 1991.

11. "Optimal Thresholds for Rainfall Measurement From Space," Wayne State, Detroit, Feb. 11, 1992.

11. "Optimal Thresholds for Rainfall Measurement From Space," University of Connecticut, Storrs, CT, March 19, 1992.

12. "Prediction of Level Exceedances ," Systems Research Center, UOM, April 3, 1992.

13. "A sinusoidal Limit, Harmonic Analysis Seminar," University of Maryland, Math. Dept., April 8, 1992.

14. "A Challenge of a NASA Earth Probe Mission: How to Measure Rainfall From Satellites When You Can't...," Undergraduate Math Colloquium, April 29, 1992.

15. "Improving the AR approach of frequency estimation by parametric filtering," (with T. Li), Penn State, May 6, 1992.

15. 1. "Partial likelihood analysis of logistic regression for dependent data," Santaiago de Compostela, Spain, June 30, 1992. 2. "Contraction Mappings in Frequency Estimation," Santaiago de Compostela, Spain, July 2, 1992.

16. "Amending the AR Method for Frequency Detection by Parametric Filtering," Technion, Israel, July 14, 1992.

17. "A challenge of a NASA earth probe mission...," 5'th Latin American Congress of Probability and Mathematical Statistics, Sao Paulo, Brazil, June 28-July 3, 1993.

18. "Amending the AR method for frequency detection by parametric filtering," Time Series and Econometrics Meeting, Sao Paulo, Brazil, July 5-7, 1993.

19. Statistics Seminar on HOC, Oxford, England, October, 1993.

4 Workshop

Our research was presented in a special workshop titled *"SIGNAL PRO-CESSING BY ZERO-CROSSINGS,"* held at Mathematics Department, University of Maryland, College Park, on March 4, 1992.

5 Honors/Awards/Prizes

1. B. Kedem, Visitor at the Systems Research Center, University of Maryland, 1991-6.

2. B. Kedem was invited by Tsinghua University, Beijing, China, to give a sequence of lectures on HOC, Dec. 22, 1990-Jan. 10, 1991.

6 Ph.D.'s

1. Martin, D.E.K. (1990). *Estimation of the minimal period of periodically correlated sequences.*

2. Lopes, S. (1991). *Spectral analysis in frequency modulated models.*

3. Pavlopoulos, H. (1991). *Statistical inference for optimal thresholds.*

4. Troendle, J.F. (1991). *An iterative filtering method of frequency detection in a mixed spectrum model.*

5. Li, T. (1992). *Multiple frequency estimation in mixed-spectrum time series by parametric filtering.*